Chapter 10
Synthesis and Recommendations

Martin Junginger, Chun Sheng Goh, and André Faaij

Abstract In this chapter, the main insights and lessons of the book are synthesized, providing an overview of trade flows and key findings on amongst others the importance of biomass trade in relation to policies, logistics, sustainability. Based on that, recommendations are formulated for policy makers, NGO's, industry and academia how to further develop international bioenergy trade. The chapter is closed by a vision on future bio-based economy, international markets and trade. We show that while bioenergy trade is not a goal on its own, and that substantial challenges for the future development of global and international bioenergy trade may be expected in the coming decades, trade is a crucial prerequisite to balance demand and supply on an international scale and in a sustainable manner which will lead to the development of bioenergy as a carbon-neutral alternative to fossil fuels. At the same time, trade can mobilize rural areas around the world into becoming key energy producers and exporters which in turn can contribute to poverty alleviation and further development and modernization of the agricultural sector. However, such developments will need governance frameworks and best industry examples to ensure sustainable production, trade and use – and this book provides many state-of-the-art insights in what can be learned from current market experiences, certification efforts, logistics and preconditions with respect to policy and investment.

M. Junginger (✉) • C.S. Goh • A. Faaij
Copernicus Institute, Utrecht University, Utrecht, The Netherlands
e-mail: h.m.junginger@uu.nl; c.s.goh@uu.nl; a.p.c.faaij@uu.nl

M. Junginger et al. (eds.), *International Bioenergy Trade: History, status & outlook on securing sustainable bioenergy supply, demand and markets*, Lecture Notes in Energy 17,
DOI 10.1007/978-94-007-6982-3_10, © Springer Science+Business Media Dordrecht 2014

10.1 Main Insights and Lessons from This Book

10.1.1 Bioenergy Trade in a Nutshell

While the overall use of modern bioenergy has increased gradually over the past decades in many countries of the world, international bioenergy trade is a phenomenon that has grown from virtually nothing to substantial volumes in little more than a decade (2000-current), with internationally traded volumes typically increasing by a factor of 10 or more over this period. Main biomass fuels traded over long distances are liquid transport fuels (ethanol and biodiesel) and refined solid biomass (wood pellets and to a lesser extent wood chips). At the moment, liquid and solid biofuels markets are significantly different. The liquid biofuels markets are reasonably developed markets and are closely related to agriculture commodities. Solid biofuels basically originated from the forestry and wood processing sector, and are mainly used in renewable electricity and heat production. The markets are less complex and trade dynamics are more straightforward. By 2011, close to 2,500 PJ of liquid biofuels were produced globally; over two-third of which were fuel ethanol and the remaining biodiesel. About 300 PJ of liquid biofuels were traded internationally in 2011, of which roughly two-thirds biodiesel. The feedstock base is exclusively regionally specific oil, sugar, or starch crops. Global trade in biodiesel has been and will in the foreseeable future be primarily driven towards the European Union, where renewable energy policies stimulate the consumption of sustainable transport fuels – although the EU biofuels market growth is slowing down. Fuel ethanol is largely produced and consumed in the Americas, with the USA and Brazil dominating global production, trade and deployment. In comparison, solid biomass trade for energy has also reached over 300 PJ by 2011. The majority of this volume comprises of wood pellets and wood chips aimed for consumption in the European Union (EU). Wood pellets are the largest single commodity stream and have seen a rapid production growth and trade internationalization. This is primarily due to past and expected future EU demand developments in the industrial segment. Belgium, the Netherlands, the United Kingdom, and Denmark in particular are bound to increase consumption, and will remain net pellet importers. To a lesser extent, solid biomass is also traded in unrefined (such as palm kernel shells). Also, indirect trade of biomass is significant: large amounts of biomass is traded primarily for material purposes (e.g. sawn wood, pulp, animal fodder), but after further processing and final use in the destination country, large amounts of these streams still end up as fuel in the wood and paper industry or in municipal solid waste, which is increasingly combusted with electricity and/or heat production.

10.1.2 Policy as Main Driver

It is obvious from many chapters in this book that policies supporting the increase demand in biomass as part of renewable energy policies (both liquid biofuels and solid biomass) have been the single-most important driver behind this increase in trade. Other potential drivers (increased fossil fuel prices, prices for CO_2, security of supply/geopolitical concerns, policies to stimulate biomass production/export) have all been (far) less important to date. While these are expected to increase in importance in the more distant future, up till 2020, the renewable energy targets in the US and the EU are likely to remain the largest single driver for international bioenergy trade until 2020. Ambitious targets in almost all OECD countries are likely to lead to further increasing imports of biomass in the near future. While in the previous decade, increasing oil- and coal prices fostered the hope that renewables would become cost-competitive o a direct comparison (i.e. without taking externalities into account), this has become less likely with the effects of (cheap) shale gas and oil also indirectly lowering the prices of coal. Maintaining renewable energy targets (and effective support policies to reach them) is thus of undiminished importance.

10.1.3 The Importance of Sustainability

The main rationale for bioenergy deployment is to enable society to transform to more sustainable fuel and energy production systems. Thus, sustainability safeguards are needed. These can be either through binding regulations and/or voluntary systems, both for domestic and imported biomass. There is currently a high number of initiatives and a proliferation of schemes. Markets would gain from more harmonization and cross-compliance, but also need a good balance between complexity and accessibility. If too many or too complex indicators are implemented, the certification process becomes too demanding, costly and difficult to manage and thus not attractive for users. Too little detail will lead to different interpretation of the principles and may increase the risk of ‘green-washing’. A common language is needed as ‘sustainability’ of biomass involves different policy arenas and legal settings. Standardization has proven to be very important (in other sectors) to create transparent markets and thereby facilitate rational production and trade. Design of sustainability assurance systems (both through binding regulations and voluntary certification) should take into account how markets work, in relation to different biomass applications (avoiding discrimination among end-uses and users). It should also take into account the way investment decisions are taken, administrative requirements for smallholders, and the position of developing countries.

Sustainability requirements are evolving and discussions on topics like iLUC for biofuels or carbon accounting for solid biomass are creating high uncertainties for companies, which in the future may need to comply with sustainability requirements that are unknown today.. The developments in biofuels markets (such as the recent change in EU policy limiting first generation biofuels to a contribution of 5 %) show clearly that uncertainty and ongoing changes in policies and regulations cause markets to stagnate. Similarly to the lengthy ongoing debates over iLUC risks for biofuels, the carbon accounting debate for forest biomass is appearing to head in the same direction. It should be kept in mind that stakeholders are making investment decisions now which establish long-term contracts, whereas governments may evaluate their policy year by year. Therefore, policy pathways should be clear and predictable, and future revisions of sustainability requirements should be open and transparent.

10.1.4 The Role of Efficient Logistics and Pretreatment Technologies

Achieving objectives for increased use of renewable bioenergy resources will require that biomass has the characteristics needed to be bought and sold outside of its production areas, or that biomass is "tradable." Tradability is influenced by the reliability of product supply, the existence of a market demand, the opportunity for profitable transactions, the physical transferability of the product, and the guarantee of product quality. These influences are not exclusive of one another, and the more that must be done to a product to improve its tradability, the greater the cost constraint pressures become. The fundamental challenge facing an expanding bioenergy industry is that feedstock cost is presently too high for demand. A key component of reducing biomass cost is to change the format to something high-density, flowable, stable, consistent, and high quality. Making the biomass format compatible with existing high-capacity transportation and handling infrastructure will reduce the need for new infrastructure. Producing biomass with these characteristics and a cost conducive to energy production requires the development of new technologies, or improvements to existing ones.

One of these new technologies that can make biomass 'tradeable' may be torrefaction. It is a thermochemical treatment that drives off moisture and volatiles, and produces an energy-dense, homogenous, stable, and easily transported feedstock product. The product lacks bulk density, which can be improved using densification technologies such as pelletization to increasing dry matter bulk density and address feedstock mobility and durability issues that are coupled to long-distance transport and logistics. There are many advantages to densification, including improved handling and conveyance efficiencies, controlled particle size distribution for improved uniformity, improved stability, quality improvements, and improved performance in conversion systems. Currently, however, these technologies are often energy intensive and too costly.

10.1.5 Tradeable Feedstocks and the Biorefinery

As demand for bioenergy increases, the amount of feedstock resources required to support production will be significant. To meet feedstock needs, a typical biorefinery may receive a variety of feedstocks, e.g. switchgrass, corn stover, miscanthus and/or eucalyptus, depending on location and availability. These feedstocks vary widely in composition and recalcitrance, and would require biorefineries to optimize (and possibly re-engineer) their processes for each different type of biomass, thus increasing costs. Complicating this further is that feedstock diversity varies markedly from region to region, and each feedstock within a region varies from year to year based on weather conditions, handling, storage, and crop variety. This will result in different types of biorefineries needed in every region which will further increase costs for construction and operation since there will be no "standard" biorefinery. Least-cost formulation, in conjunction with mechanical preprocessing and preconversion technologies, offers a promising solution to these issues by combining feedstocks to achieve desired feedstock specifications, reduce undesirable properties, and simplify downstream processing. This approach leverages technology advances to address transport and logistics challenges and convert raw biomass into feedstocks that are easily traded outside their production areas.

10.1.6 Barriers

Barriers restricting the development of bioenergy trade include technical and tariff barriers currently mainly affect liquid biofuels. Import tariffs and anti-dumping measures have been the topic of dispute between the main producing and consuming regions of ethanol and biodiesel for the last decade, and also technical standards for biodiesel have been criticized, as they may put biodiesel made from soy and palm kernel oil at an disadvantage. For solid biomass, phytosanitary measures are one of the most important barriers preventing the trade of softwood wood chips for energy. Also health and safety issues related to transporting and storing solid biomass still need further attention. Finally, also the lack of good biomass (liquids and solids) production, trade & use statistics as a limiting factor to trade is mentioned in several chapters.

10.1.7 Future Demand

While international biomass trade is likely to continue to grow, it is questionable whether it will be able to maintain its exponential grow for the next decades. This would however be necessary to reach the amounts required in several model scenarios, which display large regional demand vs. supply gaps – a fact which is currently likely underestimated by policy makers and modelers etc. alike. Without significant bioenergy trade between world regions, no (or only much more limited) significant growth of bioenergy is achievable. Hence, either major challenges regarding social, ecological, technical, logistical, economic aspects of international bioenergy trade will have to be solved, or the objectives of significant higher bioenergy use have to be reduced.

10.1.8 Economic Opportunities

Setting up long-distance supply chains may then also offer a broad array of interesting investment opportunities that could offer stable, long term and high returns. But under the current investment climate in many parts of the world, investment in bioenergy supply chains is perceived by the finance sector to be risky and uncertain and therefore many projects do not materialize. At present, insufficient financing is an obvious obstacle, and so far mainly large energy companies are the largest single group of investors into bioenergy and international bioenergy supply chains. Institutional and private investors will have to step up and increase investments in bioenergy trade – possibly through dedicated bioenergy trade equity funds, and policy makers would have to create the boundary conditions (through favorable policy and investments in infrastructure). Other bioenergy market parties, e.g. the small and medium scale heat markets, small fuel producers, independent agents and distributors will also have to become more actively involved in international bioenergy trade.

10.2 The Way Forward – Actions Required from Stakeholders

Further expanding bioenergy trade is thus an extraordinary challenge, which will require action from all stakeholders involved. Below, we discuss in more details what will be needed from each stakeholder group to make this happen.

10.2.1 Policy Makers

Given the continued dependence of renewable energy sources on policy support, first and foremost, there is a strong need to set clear and binding long-term targets for renewable energy and GHG emission reduction targets, especially beyond 2020, preferably on an international level. Linked to this, also the framework of economic support policies should be permanent and internationally harmonized. International mandates for the use of renewable energy in general and bioenergy specifically focusing primarily on the transportation, heat and power sectors have proven to be effective, as have direct subsidies in individual investments along the biomass to energy value chain. National stop-and-go policies have proven to disrupt the market significantly.

In parallel, also an internationally widely accepted framework on the sustainable production of biomass for energy, material use and other purposes should be established. While scientific insights on the sustainable production of biomass progress over time, and sustainability criteria may be sharpened as the industry learns, again, such changes should be introduced gradually, with sufficient time for all stakeholders in the supply chain to adapt.

As sustainability of biomass and bioenergy is politically important in the context of carbon mitigation policies, transparent and consistent monitoring systems should be established to minimize the risk of confusion, improve the reliability of trade information, facilitate the discussions between policy makers, NGOS and industry, and support sustainable international bioenergy trade.

Next to these general recommendations to promote the sustainable production and use of bioenergy, policy makers must also realize the logistic challenges that go hand in hand with developing large-scale bioenergy trade. Biomass trade will have to reach the dimensions similar to those of coal or oil today, which presents a tremendous challenge, as biomass is typically produced decentralized, and thus needs to be collected form wide and should enable and stimulate investments in infrastructure, especially in exporting countries, e.g. by creation of suitable import and export legislation for bioenergy products. In addition, countries that currently still have tariff barriers in place may consider to remove them. If done globally, this would create a more level playing field for producers, and could ultimately also lead to lower cost of policy support measures.

Linked to the logistic challenges, support for the development of new technologies for efficient collection, pretreatment and transport of bioenergy is indispensable to further lower the costs of logistics on the longer term.

10.2.2 NGO's

Many NGO's have in recent years increasingly opposed bioenergy in general; first focusing on first generation liquid biofuels, and more recently also on the use of forest biomass. Underlying concerns are impacts on biodiversity, food security and timing before GHG savings are obtained. While these concerns are in principle all valid, and safeguards have to be established to prevent the use of unsustainably produced biomass, NGO's have a tendency to (unknowingly or deliberately) sketch worst case scenarios, which have often little or no relevance to actual ongoing industry practices. One prominent example is the carbon debt debate, where opponents often assume that entire old-growth forests are integrally cut down and used for energy and heat production, whereas in reality, typically only residues and thinnings from plantations and sustainably managed forests are used, and these – at least currently – only contribute an very minor share of the modern bioenergy use in OECD countries. Similarly, NGO's have often objected against the long distance trade of bioenergy, claiming that energy losses would be prohibitive, while scientific studies have shown repeatedly, that long-distance trade – if organized right, does not cause prohibitive energy losses, i.e. 10–20 % of the energy content, which is no more than e.g. electricity losses from offshore wind farms transported long-distance to demand centers, or solar electricity transported from the Sahara to Southern Europe. While the importance of NGO's to point out unsustainable practices and black sheep is not disputed, their aims and actions in recent years seem to have gone too far. We therefore encourage NGO's to be more pro-active: to accept bioenergy in general as part of the solution rather than of the problem, and focus on how sustainable production and trade (including ecological and social benefits) can be established. Such pro-active roles can for example be achieved by participating in roundtables on the development of certification schemes.

10.2.3 Academia

Task 40 has had a large number of academic institutes amongst its member since the start, and for good reasons. With the development of bioenergy trade, all kinds of questions have risen (and continue to rise), as diverse as the development of effective measures against health and safety hazards, setting up reliable bioenergy trade statistics, delivering integrated assessments of biomass producing & sourcing regions (including economic, social and environmental aspects), developing advanced biomass pretreatment methods et cetera. Nevertheless, science has in some ways also not been able to deliver: for example, regarding both the iLUC and the carbon accounting of forest biomass, different scientific views exist, and there is little consensus on the correct calculations methods and choice of reference systems. There is a clear need for scientists to both highlight the uncertainties in the current studies and at the same time improve these tools to provide policy makers and other stakeholders high-quality information for decision making. As a general recommendation, also scientists should communicate (better) with other stakeholders, especially industry, to signal early warning lights, but also to learn what current industry practices are and what questions from market actors need to be answered.

10.2.4 Industry

Last but not least, the industry itself is called upon as the most important party to further develop bioenergy trade. As already argued in Chap. 9, industry will need to assure sustainability of feedstock production through certification. While formal certification might be required in early phases of an emerging bioenergy trade development to motivate political support measures and to safe-guard against abuse, it is likely that the bioenergy trade will develop more transparency and that other measures could replace formal certification, e.g. verification and monitoring carried out by the trading parties and other stakeholders. An established trade would mean that parties in the links have a genuine interest in smooth performance and in avoiding criticism from third parties.

The industry will also need to balance supply and demand more carefully through focus on integrated supply chains to develop the market. Such an approach will inherently guarantee security of supply for each investment and reduce an important risk factor by doing risk so while at the same time reduce financing costs.

Another key aspect is to foster commoditization of specification driven bioenergy carriers for international trade through international cooperation on standardization and harmonization. This approach would quickly increase the liquidity of the biomass feedstock and biofuel market and allow for better risk mitigation and sourcing flexibility as well as for more investment into direct feedstock production.

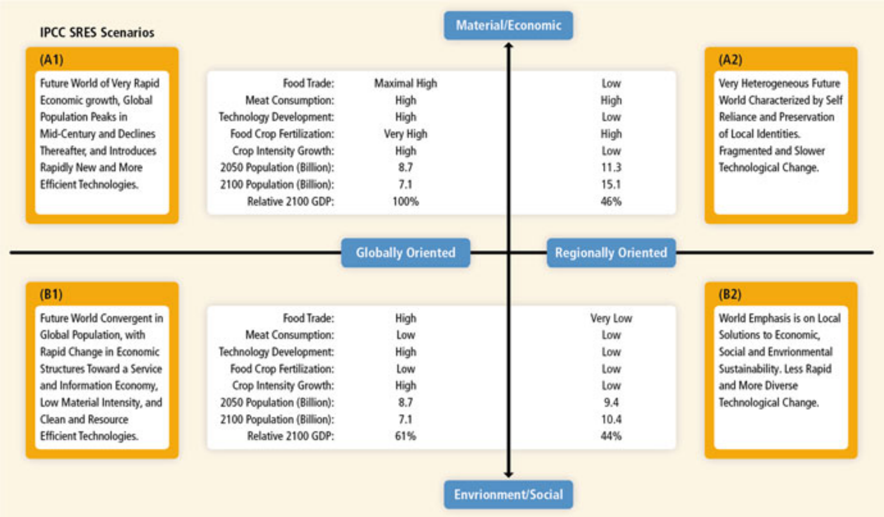
Finally, the focus will need to be put on a few preferential bioenergy products that have the potential to be produced, shipped and used in large quantities worldwide. This would allow for an even faster growth of certain supply markets, reduce insecurity within a nascent industry and mobilizes even more financial resources. Economies of scale are significant in the bioenergy value chain and reduced overall costs could eventually lead to independence from any political support schemes in certain energy sectors – as is nowadays happening already for domestic heating applications.

10.3 Closing Remarks; a Vision on Future Bio-based Economy, International Markets and Trade

In the introduction of this book, a mixed picture was sketched with respect to future biomass deployment: In state-of-the-art energy and GHG mitigation scenario's, biomass plays an essential role in meeting ambitious GHG mitigation targets, in particular for transport fuels (including growing demand from aviation and shipping) and feedstocks for chemical industry. Biomass shares in total energy supply are hoped to achieve 20–30 % looking at long term strategies and scenarios of countries as well as on a global scale. Recent scenario's stress the importance of combining large scale bioenergy use with carbon capture and storage, because this is one of the few options available to achieve net negative emissions and keep a global 2 °C temperature change target in sight during this century; a target widely seen as essential to limit the damage of climate change (GEA 2012).

Opportunities achieving synergies with rural development and ecosystem services are key benefits that could be realized in conjunction with such large scale bioenergy deployment. But achieving such an optimal outcome, comes with a large number of preconditions, most notably with respect to governance of land use & natural resources and modernization of agriculture. Furthermore, in many areas improved technologies and more experience is needed to improve environmental performance and economics, This is true for advanced technologies (fuels, biomaterials, power, carbon management such as the combination of bioenergy and carbon capture and storage), cropping systems in many different settings, further development and optimization of infrastructure, logistics, functional markets and chain of custody control. Last but not least, effective business models & investments are required.

It is by no means certain that such a mix of preconditions will be secured, despite the strong drivers to do so. Given the expectations for a high bioenergy demand on a global scale, the pressure on available biomass resources will increase. Without the further development and mobilisation of biomass resources (e.g. through energy crops and better use of agro-forestry residues) and a well-functioning biomass market to assure a reliable and lasting supply, those ambitions will not be met. Deployment of biomass may therefore remain fairly low at a 100 EJ level in 2050 as argued by the IPCC Special Report on Renewable Energy report. This is



(A1) Future World of Very Rapid Economic growth, Global Population Peaks in Mid-Century and Declines Thereafter, and Introduces Rapidly New and More Efficient Technologies.

(A2) Very Heterogeneous Future World Characterized by Self Reliance and Preservation of Local Identities. Fragmented and Slower Technological Change.

Food Trade:	Maximal High	Low
Meat Consumption:	High	High
Technology Development:	High	Low
Food Crop Fertilization:	Very High	High
Crop Intensity Growth:	High	Low
2050 Population (Billion):	8.7	11.3
2100 Population (Billion):	7.1	15.1
Relative 2100 GDP:	100%	46%

(B1) Future World Convergent in Global Population, with Rapid Change in Economic Structures Toward a Service and Information Economy, Low Material Intensity, and Clean and Resource Efficient Technologies.

(B2) World Emphasis is on Local Solutions to Economic, Social and Envrionmental Sustainability. Less Rapid and More Diverse Technological Change.

Food Trade:	High	Very Low
Meat Consumption:	Low	Low
Technology Development:	High	Low
Food Crop Fertilization:	Low	Low
Crop Intensity Growth:	High	Low
2050 Population (Billion):	8.7	9.4
2100 Population (Billion):	7.1	10.4
Relative 2100 GDP:	61%	44%

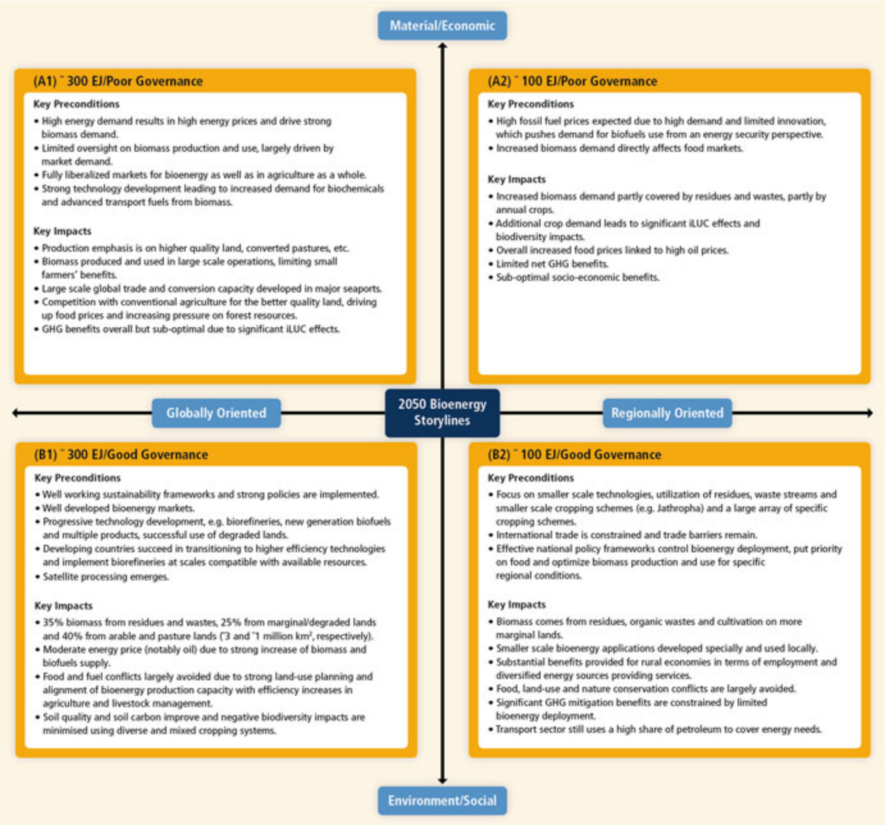
Fig. 10.1 Storylines for the key scenario variables of the IPCC Special Report on Emissions Scenarios (SRES)

illustrated by Figs. 10.1 and 10.2 (Chum et al. 2011) that sketches the “scenario space” for different futures (the so called SRES scenario’s). Figure 10.1 gives the general storylines. Figure 10.2 sketches a number of main possible characteristics with respect to bioenergy deployment, related impacts and preconditions (or lack of preconditions) for the different storylines. Of course, these are scenario’s. In reality, the development pathways that could be followed could be profoundly different going from region to region across the globe and over time. Therefore, predicting future bioenergy markets and trade remains uncertain.

Model scenarios with an ambitious increase of bioenergy demand imply a huge increase in bioenergy trade, an increase by a factor of 70 between 2010 and 2030 for liquid biofuels, and by a factor of 80 for solid biomass between world regions. Such an increase would result in quantities of internationally traded biomass commodities which would be higher than the current total global bioenergy demand (i.e. larger than 50 EJ). Considering the currently very small share of internationally traded bioenergy, this would result in huge challenges and tremendous changes in terms of production, pretreatment of biomass and development of logistic chains.

At the same time, the level of international bioenergy trade shown in the model scenarios is necessary to fill the anticipated regional gap between demand and supply. Without significant bioenergy trade between world regions, a much less pronounced growth of bioenergy is achievable.

The insight into future scenarios and perspectives of bioenergy trade makes clear that substantial challenges for the future development of global and international bioenergy trade may be expected in the coming decades if a low carbon energy system is to be implemented globally. Some of these, such as the development of



(A1) ~ 300 EJ/Poor Governance

Key Preconditions

- High energy demand results in high energy prices and drive strong biomass demand.
- Limited oversight on biomass production and use, largely driven by market demand.
- Fully liberalized markets for bioenergy as well as in agriculture as a whole.
- Strong technology development leading to increased demand for biochemicals and advanced transport fuels from biomass.

Key Impacts

- Production emphasis is on higher quality land, converted pastures, etc.
- Biomass produced and used in large scale operations, limiting small farmers' benefits.
- Large scale global trade and conversion capacity developed in major seaports.
- Competition with conventional agriculture for the better quality land, driving up food prices and increasing pressure on forest resources.
- GHG benefits overall but sub-optimal due to significant iLUC effects.

(A2) ~ 100 EJ/Poor Governance

Key Preconditions

- High fossil fuel prices expected due to high demand and limited innovation, which pushes demand for biofuels use from an energy security perspective.
- Increased biomass demand directly affects food markets.

Key Impacts

- Increased biomass demand partly covered by residues and wastes, partly by annual crops.
- Additional crop demand leads to significant iLUC effects and biodiversity impacts.
- Overall increased food prices linked to high oil prices.
- Limited net GHG benefits.
- Sub-optimal socio-economic benefits.

(B1) ~ 300 EJ/Good Governance

Key Preconditions

- Well working sustainability frameworks and strong policies are implemented.
- Well developed bioenergy markets.
- Progressive technology development, e.g. biorefineries, new generation biofuels and multiple products, successful use of degraded lands.
- Developing countries succeed in transitioning to higher efficiency technologies and implement biorefineries at scales compatible with available resources.
- Satellite processing emerges.

Key Impacts

- 35% biomass from residues and wastes, 25% from marginal/degraded lands and 40% from arable and pasture lands (~3 and ~1 million km^2, respectively).
- Moderate energy price (notably oil) due to strong increase of biomass and biofuels supply.
- Food and fuel conflicts largely avoided due to strong land-use planning and alignment of bioenergy production capacity with efficiency increases in agriculture and livestock management.
- Soil quality and soil carbon improve and negative biodiversity impacts are minimised using diverse and mixed cropping systems.

(B2) ~ 100 EJ/Good Governance

Key Preconditions

- Focus on smaller scale technologies, utilization of residues, waste streams and smaller scale cropping schemes (e.g. Jathropha) and a large array of specific cropping schemes.
- International trade is constrained and trade barriers remain.
- Effective national policy frameworks control bioenergy deployment, put priority on food and optimize biomass production and use for specific regional conditions.

Key Impacts

- Biomass comes from residues, organic wastes and cultivation on more marginal lands.
- Smaller scale bioenergy applications developed specially and used locally.
- Substantial benefits provided for rural economies in terms of employment and diversified energy sources providing services.
- Food, land-use and nature conservation conflicts are largely avoided.
- Significant GHG mitigation benefits are constrained by limited bioenergy deployment.
- Transport sector still uses a high share of petroleum to cover energy needs.

Fig. 10.2 Possible futures for 2050 bioenergy deployment: Four illustrative contrasting sketches describing key preconditions and impacts following world conditions typical of the IPCC SRES storylines (IPCC 2000)

logistics, the required investments to realize production and trade, and the need to govern sustainable production of bioenergy are addressed in this book. Others are still open for further research, e.g. the implications of bioenergy trade for specific regions and for different biomass commodities in terms of social, ecological and economic impacts or the effect of fluctuating exchange rates, regional development of economic and policy side conditions.

Biomass trade is not a goal of its own. But balancing demand and supply on an international scale and in a sustainable manner will lead to further CO_2 emission reductions and offer new chances for rural regions, degraded areas worldwide and in particular in developing countries. In that sense, the developing international bioenergy markets also represent an extraordinary opportunity: If indeed the global bioenergy market is to develop to a size of 300 EJ per year over this century (compared to 500 EJ current total global energy use), the value of that market at US$ 6/GJ (considering pre-treated biomass such as pellets) would amount to some US$ 1.8

trillion per year. Logically, not all biomass will be traded on international markets, but such an indicative estimate makes clear what the economic importance of this market can become for rural areas worldwide, as are the employment implications.

It is exactly there that the possibilities and potentials for modern bioenergy production, including export, are largest and at the same time the need for development of rural areas is the highest. These crucial issues, global bioenergy markets and rural development, merge in a formidable way.

Given the scale of the market, bioenergy trade could provide one of the most important sustainable development pathways for decades to come: developing bioenergy as the key sustainable and carbon-neutral alternative to fossil fuels and at the same time mobilizing rural areas around the world into becoming key energy producers and exporters could contribute to poverty alleviation and further development and modernization of the agricultural sector. The latter is extremely important for sustainable development of agriculture and food security at large, while lowering the footprint for food production and allowing biomass production without unsustainable land use change.

Although biomass production may well provide a crucial strategy to enhance sustainable land-use management, negative developments should be avoided, e.g., by clear standards and best-practice guidelines for (the design of) biomass production systems and their integration in agricultural areas.

Gaining further experience with certification, developing and implementing the necessary governance frameworks on land use, removing trade barriers and showing best-practice operations through export-oriented production schemes in a diversity of developing countries and different rural areas are crucial in the short term. This book has provided many state-of-the-art insights in what can learned from current market experiences, certification efforts, logistics and preconditions with respect to policy and investment. Good examples, successful business models and effective frameworks can guide market forces in a sustainable direction. When successful, the Green OPEC (or BIO-PEC) may become a reality in several decades from now!

References

Chum, H., Faaij, A., & Moreira, J., (CLA's), Berndes, G., Dhamija, P., Dong, H., Gabrielle, B. X., Goss Eng, A. M., Lucht, W., Mapako, M., Masera Cerutti, O., McIntyre, T. C., Minowa, T., Pingoud, K., Bain, R., Chiang, R., Dawe, D., Heath, G., Junginger, M., Patel, M., Yang, J. C., & Warner, E. (2011). Chapter 2, Bioenergy. In O. Edenhofer, R. P. Madruga, & Y. Sokona et al. (Eds.), *The IPCC special report of the* Intergovernmental Panel on Climate Change*: Renewable energy sources and climate change mitigation*. New York: Cambridge University Press. Available at: http://srren.ipcc-wg3.de/report/IPCC_SRREN_Ch02.pdf

GEA. (2012). *Global Energy Assessment – Toward a sustainable future*. Cambridge/New York/Laxenburg: Cambridge University Press/The International Institute for Applied Systems Analysis.

IPCC. (2000). *Summary for policymakers. Emissions scenarios*. A special report of IPCC Working Group III. Available at: http://www.ipcc.ch/pdf/special-reports/spm/sres-en.pdf